



DoD Executive Agent

Office of the
Assistant Secretary
of the Army
Installations, Energy and
Environment

Power System Implementation and Demonstration at Camp Katuu, Palau

**Clark Boriack, NDCEE/CTC
E2S2, New Orleans
May 11, 2011**

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Report Documentation Page				Form Approved OMB No. 0704-0188	
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1. REPORT DATE 11 MAY 2011		2. REPORT TYPE		3. DATES COVERED 00-00-2011 to 00-00-2011	
4. TITLE AND SUBTITLE Power System Implementation and Demonstration at Camp Katuu, Palau				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) National Defense Center for Energy and Environment (NDCEE), Concurrent Technologies Corporation, 100 CTC Drive, Johnstown, PA, 15904				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES Presented at the NDIA Environment, Energy Security & Sustainability (E2S2) Symposium & Exhibition held 9-12 May 2011 in New Orleans, LA. U.S. Government or Federal Rights License					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 30	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

Outline

- Demonstration Overview
 - Site review
 - Demonstration goals
- Development and Design Considerations
 - Layout
 - Electrical
 - Mechanical
- Critical Design Aspects
 - Safety
 - Component selection
 - Local electrical utility performance

Site Review



- Camp Katuu, located near Koror, Palau; latitude of 7° 30' North
- NREL PVWatts™ did not have Palau in the historical database so Awassa, Ethiopia; 7° 3' North latitude was used

Demonstration Goals

- Camp Katuu Installation
 - Increase civil outreach and nation building with Palau Government
 - Reduce environmental footprint at Camp Katuu
 - Increase use of alternative energy
 - Demonstrate the feasibility of using alternative energy in the region
 - Quantify PV system performance/capability
 - Train 249th Engineer Battalion to install Photovoltaic Systems
 - Validate camp electrical costs reduction
- Future Installations
 - Leverage design aspects for other remote installations (grid frequency and voltage regulation, corrosion, high electricity costs)
 - Next generation to include off-grid operation capability with energy storage

Development and Design Considerations

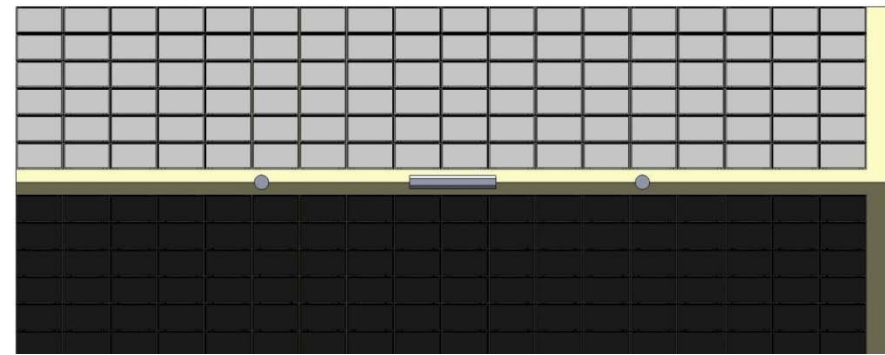
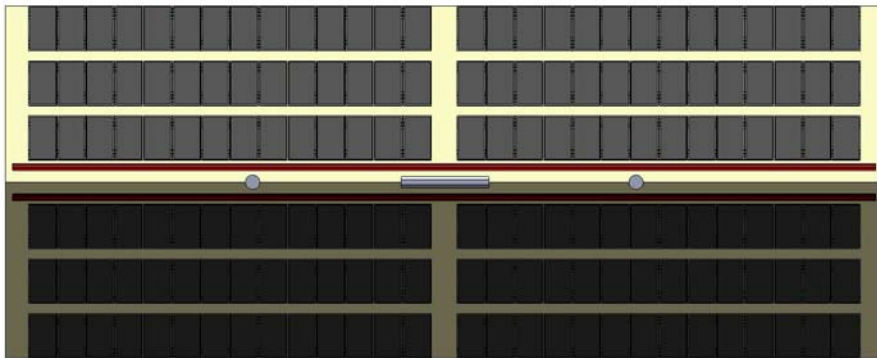
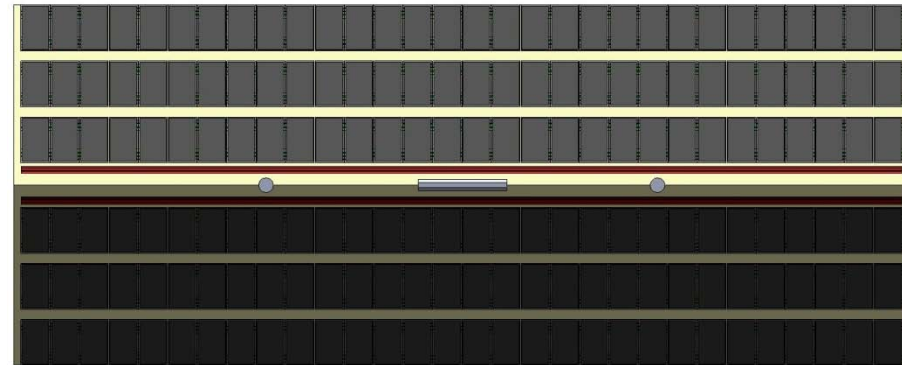
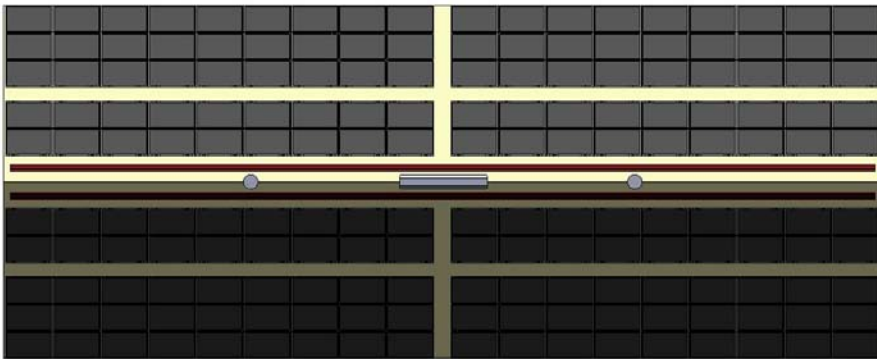
- PV System Layout Considerations
 - Access ways for installation, repair, maintenance
 - Ease of installation
 - Maximize system rating



Camp Katuu Builder's Shop – PV Array Installation Location

Development and Design Considerations

- PV System Layout Options Considered



Development and Design Considerations

- PV System Layout Considerations

PV LAYOUT OPTION SUMMARY					
No.	Consideration	Option 1	Option 2	Option 3	Option 4
		5 Horizontal Rows	3 Vertical Rows	3 Vertical Rows with Center Walkway	6 Vertical Rows
1	Amount of rail mounting (lf)	1440'	1800'	1800'	1440'
2	Ease of rail installation	some rail cutting required to clear walkway	requires two level rail mounting system	requires two level rail mounting system	no rail cutting required
3	Ease of wiring	Intuitive circuit pattern	Very Intuitive circuit pattern	Very Intuitive circuit pattern	odd circuit pattern
4	Maintenance access	21" horizontal & vertical walkway, does not have direct access to all panels	Accessible with 15" walkways	Direct access to each panel and has a center walkway	No direct access to most panels
5	System DC Rating (kW DC) [1]	42.300	42.300	39.480	50.760
6	System AC rating (kW AC) [2]	32.571	32.571	30.400	39.085
7	Fall Protection System	accommodates rail system	accommodates rail system	accommodates rail system	does not accommodate rail system
8					

Color Legend

most favorable

more favorable

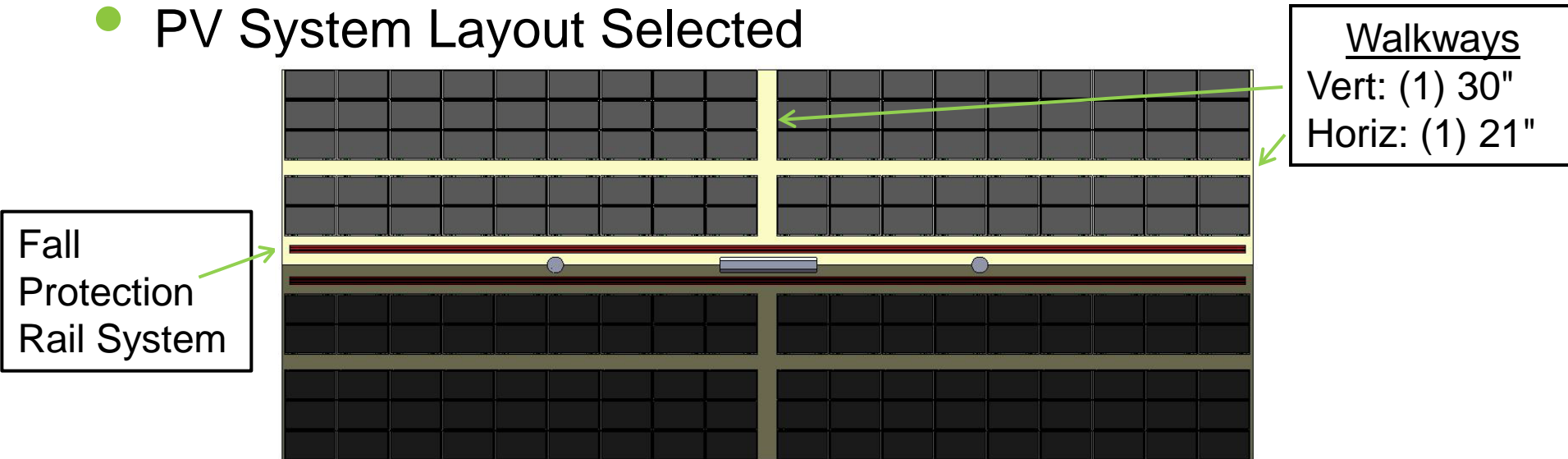
least favorable

Note [1] System DC Rating based upon use of 235W solar panels

Note [2] System AC Rating based upon typical .77 conversion factor from DC power to AC power

Development and Design Considerations

- PV System Layout Selected



No.	Consideration	Impact
1	Amount of rail mounting (lf)	1440'
2	Ease of rail installation	some rail cutting required to clear walkway
3	Ease of wiring	Intuitive circuit pattern
4	Maintenance access	21" horizontal & vertical walkway, does not have direct access to all panels
5	System DC Rating (kW DC) [1]	42.300
6	System AC rating (kW AC) [2]	32.571
7	Fall Protection System	accomodates rail system

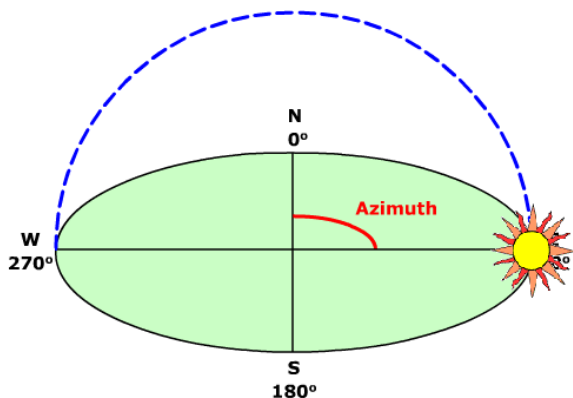
Color Legend

most favorable
more favorable
least favorable

Economics

Array Azimuth Angle

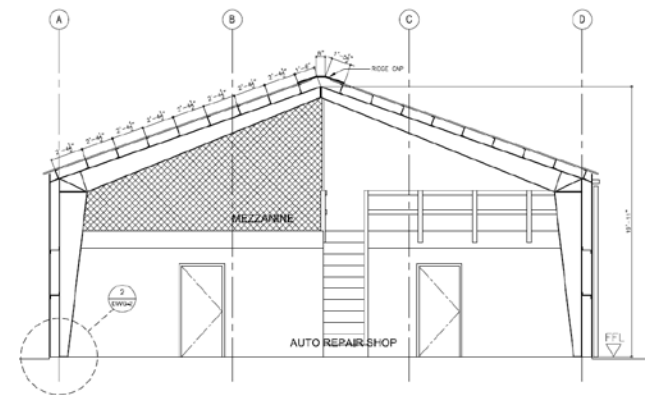
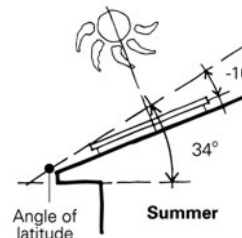
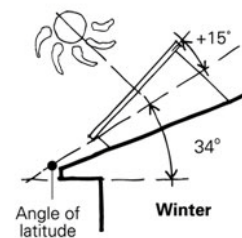
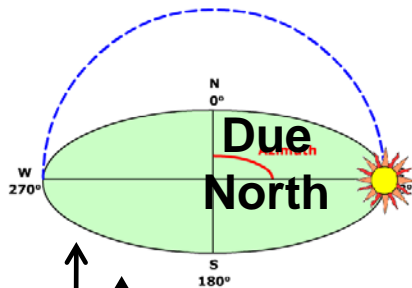
- The array azimuth angle is defined as the clockwise angle of the array face from true north



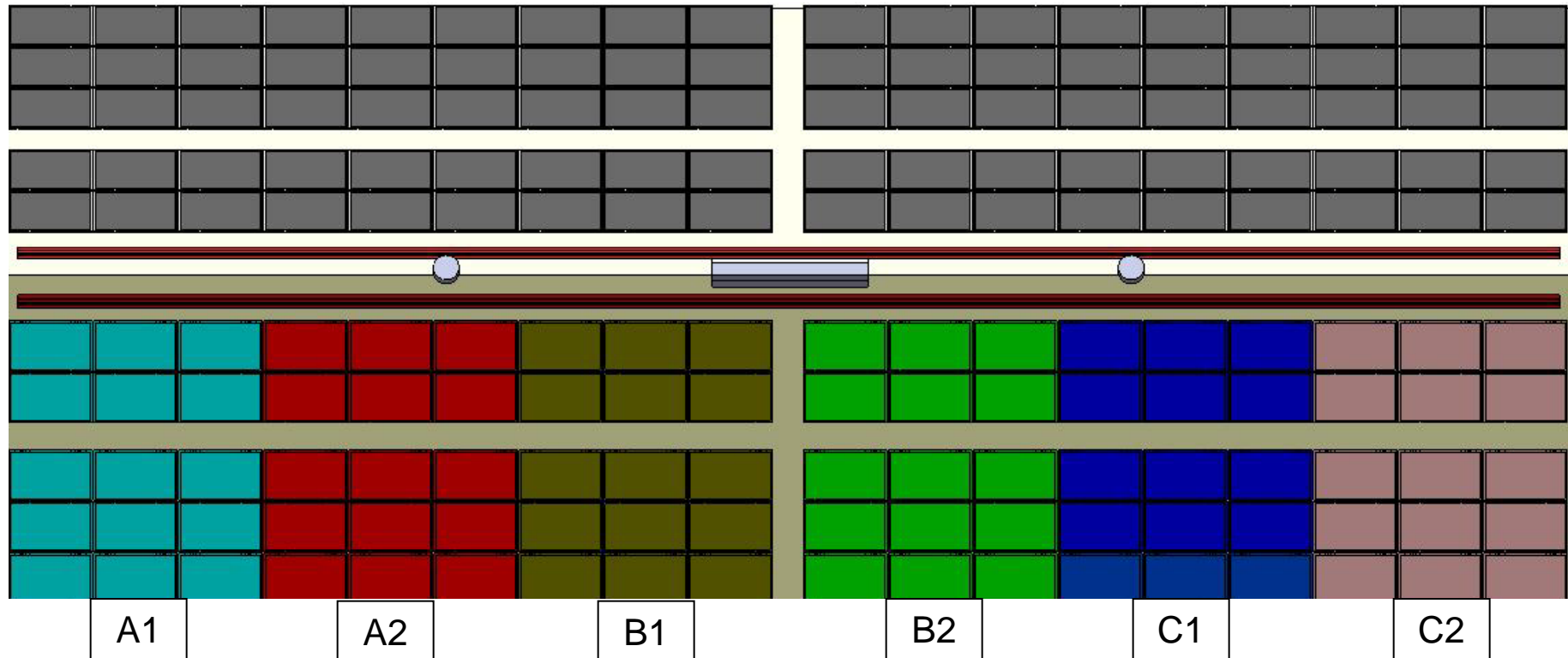
Economics

Array Tilt Angle

- The array tilt angle is the angle of the array face to the sun's rays
- 4:12 pitch of Builder's Shop roof provides a tilt angle of 18°
- Ideal 7° pitch improved annual savings from \$21.8k to \$22.5k



Development and Design Considerations

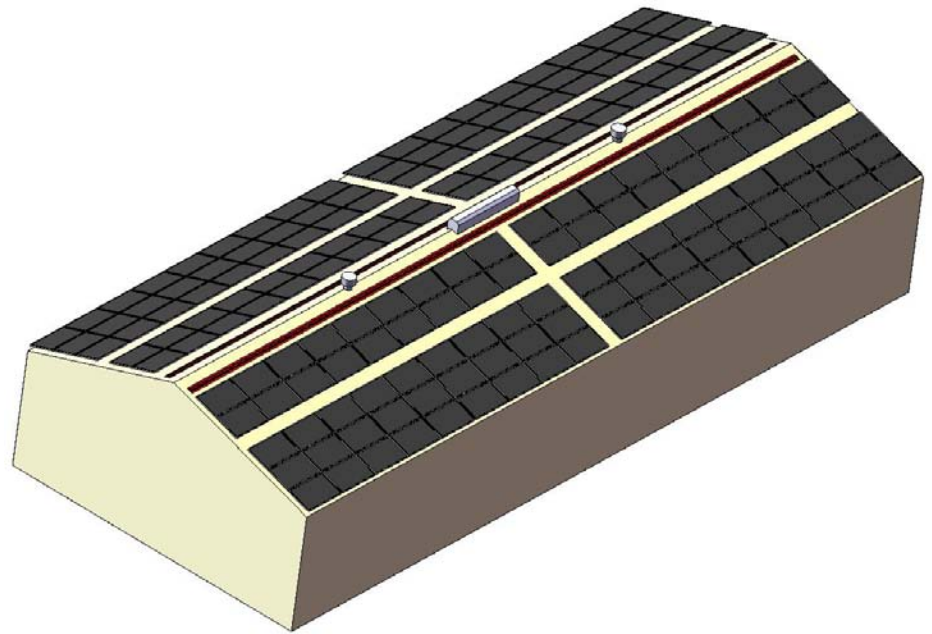


- Two Groups of 15 panels for each inverter for each side of roof
- Balanced 3 phase system
- Both circuits for each inverter on same side of roof
- Logical organization to support installation/sustainment

Critical Design Aspects

Safety

- Safety Railing
 - Maximizes Safety Considerations
 - Supports installation
 - Supports maintenance
- Access Ways
 - Supports installation
 - Supports maintenance
 - Beginning to be required



Safety Rail Systems

- Horizontal Cables
 - Pre-engineered but require installation and load testing by a certified vendor
 - Higher mounting height minimizes the possibility of rope catching on panels
- Single Point Anchors
 - Limited mobility and low ease of use
 - To move from anchor to anchor, must first tie off on second anchor, return to unhook, then move to work area
 - Inexpensive equipment and installation
 - Requires heavy gage material for attachment
- Horizontal Rails
 - Pre-engineered so installation and design costs are minimal
 - Does not require installation and/or inspection by a certified vendor
 - Mounts very close to roof – rope may catch on edges of panels



Cost Benefit Comparison

System Type	Equipment Cost	Design Fee	Vendor Installation Fee	Personnel Training Costs	Total Cost	Ease of Use (1-10, 10 being best)
Horizontal Rail	\$5.5k	\$0	\$0	\$5k (vendor travel cost)	\$10.5k	8
Single Point Anchors	\$4k	\$2k	\$0	\$5k (vendor travel cost)	\$11k	2
Horizontal Cable	\$10K	\$2k	\$14k	\$0 (included in installation)	\$26k	10

- The horizontal rail system is the most cost effective solution and is easy to use, therefore it is recommended for this application
- Although the single point anchors are also cost effective, they limit mobility and are not easy to use
- Horizontal cable systems require vendor installation and certification, making them the most costly - Once installed, they are the easiest to use

Fall Protection Roof Rail Systems



Figure 7: Rail Type Fall Protection System

- Systems are pre-engineered and can be installed by others
- Fosters safe, efficient travel across roof
- Product support is available for installation and training
- Estimated Material Costs
 - ~\$20k FLEXRIDGE™ System
 - ~\$6k Uniline™ System

Mounting System UNIRAC™ Method

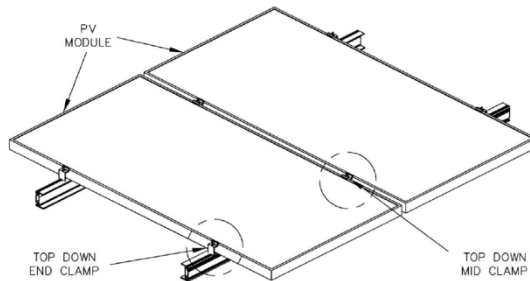


Figure 4: Roof Top Flush Mounting System

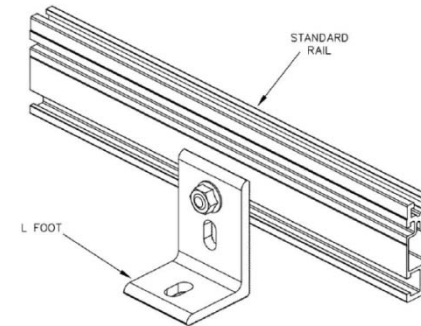


Figure 5: UNIRAC Standard Rail and L Mounting Bracket

Corrosion Contributing Factors:

- Humid, Salty climate
- Galvanic cell between dissimilar metals

Steps to Mitigate Corrosion Risks:

- Barrier material installation
- ASTM B117 corrosion testing to confirm compatibility (500hr test during April 2011)
- PV module has been tested, verified to withstand corrosion by manufacturer; 25 year warranty

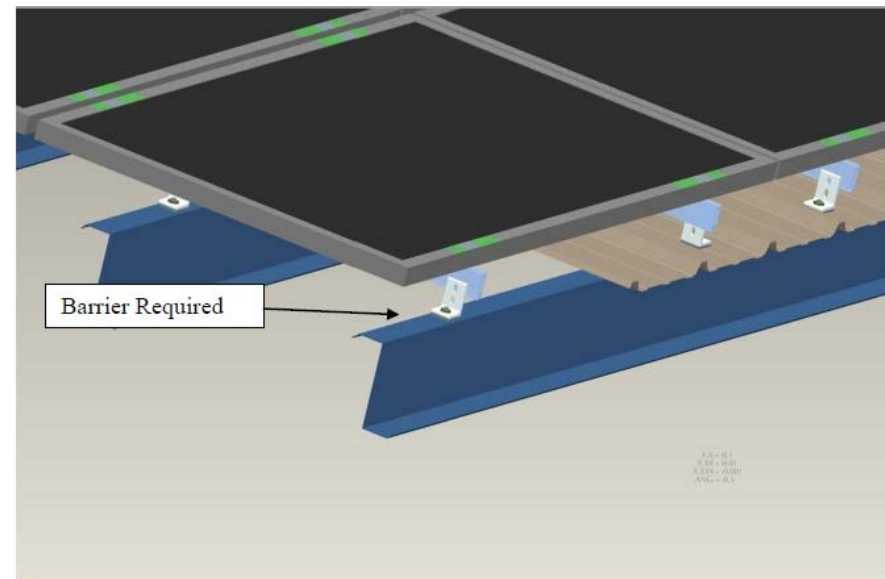
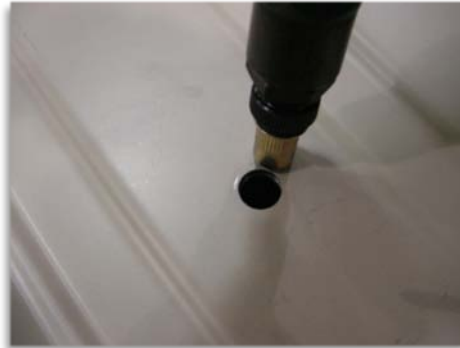
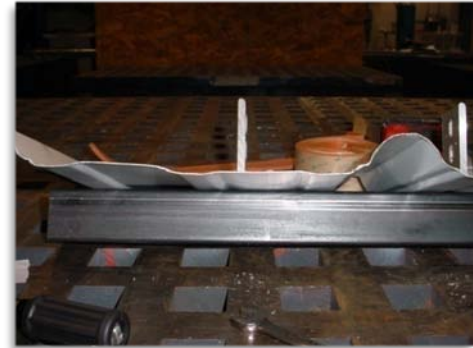


Figure 6: Rail Mounting Bracket Interface

Shop Prototype Application Corrosion Testing



Predrill



Steel Tubing



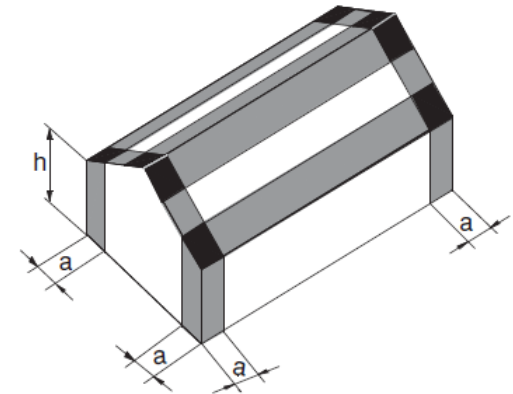
Insert Riv-nut



Final Assembly

Wind Load Distribution

- Wind load distribution for enclosed gable roof buildings is as shown
- Dimension “a” is calculated as the lesser of either:
 - 10% of the least horizontal dimension (w) $0.10 * 40'-0" = 4'-0"$
 - 0.4h
 - $0.4 * 13'-3" = 5'-4"$
- Dimension “a” is taken as 4'-0"

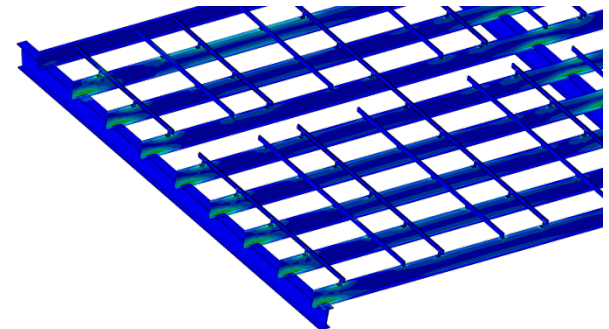
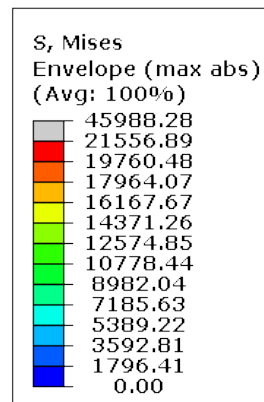


Gable Roof ($7^\circ < \theta \leq 45^\circ$)

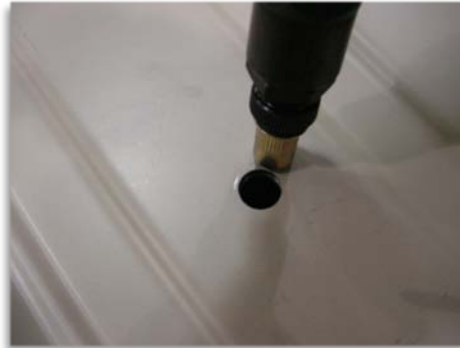
□ Interior Zones
Roofs - Zone 1/Walls - Zone 4

■ End Zones
Roofs - Zone 2/Walls - Zone 5

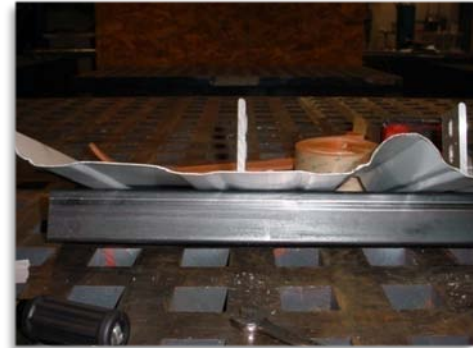
■ Corner Zones
Roofs - Zone 3



Shop Prototype Application Fastener Testing



Predrill



Steel Tubing



Insert Riv-nut



Final Assembly

Mounting System Original Fastener



Selection Guide

ECF Catalog No.†	Size	L Length	Drive System	Point Size	Max. Drilling Cap.	B Maximum Load-bearing Length*	Pieces per 1/4 Keg†	Job Pack: Pieces per Box†
Hex Washer Head								
EJ110	10-16	3/4"	5/16" hex	2	.110"	0.320"	6000	250
EJ185		1"		2	.140"	0.500"	4000	150
EJ215	12-14	1-1/2"		2	.140"	1.00"	2500	125
EJ240		2"		2	.140"	1.500"	2000	75
EJ190		1"	3/8" hex	3	.210"	0.500"	4000	150
EJ220	12-14	1-1/2"		3	.210"	1.00"	2500	125
EJ260		2-1/2"		3	.210"	2.00"	1500	50
EJ340	12-24	2"		5	.500"	1.100"	2000	75
EJ415		1"	3/8" hex	2	.175"	0.500"	3000	125
EJ430	1/4-14	1-1/2"		2	.175"	1.00"	2000	75
EJ445		2"		3	.312"	1.500"	1500	50
EJ540		1"		3	.312"	0.500"	2500	125
EJ580	1/4-20	1-1/2"	5/16" hex	2	.175"	1.00"	2000	75
EJ610		2"		3	.312"	1.500"	1500	50
EJ640		2-1/2"		3	.312"	2.00"	1000	50
EJ615	1/4-20	2"		5	.500"	1.100"	1500	50

Flat Head Reamers w/wings

EBN140	10-16	1-1/2"	#2 phillips	3	.140"	0.800"	3500	125
EBN345	12-24	2-13/16"	#3 phillips	5	.500"	1.710"	1500	50
EBN645	1/4-20	2-13/16"	#3 phillips	5	.500"	1.710"	1000	50

Flat Head Undercut

EBN200		1"	#3 phillips	2	.140"	0.500"	4000	150
EBN240	12-14	1-1/2"	#3 phillips	2	.140"	1.00"	2500	125

Performance Data

Pull-Out Values

Screw Size	Drill Point Type	Drill Cap (in.)	Pull-Out (Lbs)									
			Steel RB50-75 50 - 66KSI					Aluminum 6063-T5 22KSI				
10-16	2	0.150	455	677	793	1394	1906	—	994	—	—	—
10-16	3	0.187	—	616	684	1242	1605	1527	—	961	—	—
12-14	2	0.187	528	750	892	1536	2602	2514	—	1132	—	—
12-14	3	0.210	417	679	802	1371	2028	2499	—	974	—	—
12-24	5	0.500	—	—	—	—	2110	2781	538	1995	—	—
1/4-14	2	0.210	619	885	1082	1830	2943	3535	—	1310	—	—
1/4-20	3	0.375	—	680	780	1442	2623	3684	4069	1037	2786	—
1/4-20	5	0.500	—	—	—	—	—	2622	—	—	1724	—

Identification

The head marking consists of the number "3" above the Elco® logo as shown below.



flat head



hex washer head

* The load-bearing length is the length of 300 series stainless under the hex head or including the flat head. Hardened steel length (lead threads and point) should be through the connection and not in the load bearing section of the connection.

† Standard packaging: 1/4 keg quantities as shown.

Job Pack: Pieces per box as shown/ six boxes per shipper. Available upon request. Indicate Job Pack by placing a "P" at the end of the ECF Catalog No.

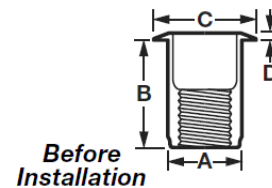
NOTE: All performance data shown is based on tests performed under laboratory conditions at independent construction testing facilities. The appropriate safety factor should be applied and code requirements factored into specification and use of these fasteners. A safety factor of 4:1 or 25% of the ultimate average values shown is generally accepted as an appropriate working load. Final determination of the appropriate safety factor and use of these fasteners is the sole responsibility of the user, specifying Engineer, Architect or other responsible person designing the connection. Due to a wide variety of application conditions or intervening factors not under our control, we assume no liability for the use of the information provided in this document. For additional product information and technical assistance, please contact Elco directly at 1-800-435-7213.

Ultimate Strengths**

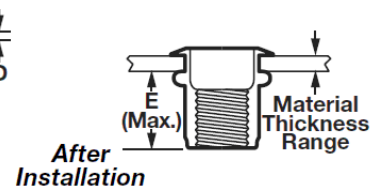
Size	Tensile (Lbs)	Shear Average Lbs Ultimate
10-16	1847	1282
12-14	2628	1950
12-24	2734	2284
1/4-14	3459	2676
1/4-20	4124	2860

** Values are for 300 series stainless fastener threaded shank

- Sufficient Pull Out Rating for load
- Insufficient for Pull Out for installation
- Select rivet-nut instead of self-drilling fastener



Before Installation



After Installation



PV Module Comparison Results

Mechanical Characteristics	Canadian Solar PVCS6P-235P	Kyocera KD215GX-LPU	Sharp PVSH ND-224 UC1	Evergreen PVES-A-210-FA3	BP PVBP3215B	BP PVBP3230T
length(in)	64.5	59.1	64.6	65.0	65.6	65.6
width (in)	38.7	39	39.1	37.5	39.4	39.4
thickness (in)	1.57	1.8	1.8	1.8	2	2
weight (lbs)	44.1	39.7	44.1	41.0	42.8	42.8
Electrical Characteristics						
power output (dc w)	235	215	224	215	215	230
panel open circuit voltage rating (volts)	36.9	33.2	36.6	23.1	36.5	36.7
panel maximum power voltage rating (volts)	29.8	26.6	29.3	18.7	29.1	29.1
panel current rating (amps)	7.90	8.09	7.66	11.23	7.40	7.90
Other Characteristics						
cost/panel	\$ 479.36		\$ 479.57	\$ 456.66	\$ 456.66	\$ 490.45
cost/watt	\$ 2.04	\$ -	\$ 2.14	\$ 2.12	\$ 2.12	\$ 2.13
power output warranty (years)	25	20	25	25	25	25
delivery (weeks)	STOCK	12	STOCK	STOCK	STOCK	STOCK

PV Module

Recommended Product



CS6P

220/225/230/235/240/245/250P



Key Features

- Top ranked PVUSA (PTC) rating in California for higher energy production
- 6 years product warranty (materials and workmanship); 25 years module power output warranty
- Industry leading plus only power tolerance: +5W (+2%)
- Strong framed module, passing mechanical load test of 5400Pa to withstand heavier snow load
- Ultra reliable in corrosive atmosphere, verified by IEC61701 "Salt Mist Corrosion Testing"
- The 1st manufacturer in the PV industry certified for ISO:TS16949 (The automotive quality management system) in module production since 2003
- ISO17025 qualified manufacturer owned testing lab, fully complying to IEC, TUV, UL testing standards

On-grid Module

CS6P is a robust solar module with 60 solar cells. These modules can be used for on-grid solar applications. Our meticulous design and production techniques ensure a high-yield, long-term performance for every module produced. Our rigorous quality control and in-house testing facilities guarantee Canadian Solar's modules meet the highest quality standards possible.

Applications

- On-grid residential roof-tops
- On-grid commercial/industrial roof-tops
- Solar power stations
- Other on-grid applications

Quality Certificates

- IEC 61215, IEC 61730, IEC 61701, UL 1703, CEC Listed, CE, KEMCO and MCS
- ISO9001: 2008: Standards for quality management systems
- ISO/TS16949:2009: The automotive quality management system
- QC080000 HSPM: The Certification for Hazardous Substances Regulations

- Highest Power Output
- Tested for Corrosion
- Best Value
- Stock Item

PV Module Specifications	Canadian Solar
Mechanical Attributes	
Length(in)	64.5
Width (in)	38.7
Thickness (in)	1.57
Weight (lbs)	44.1
Electrical Attributes [1]	
Nominal Maximum Power Output at STC (Pmax)	235 Watts
Voltage at Pmax (Vmp)	29.8 Volts
Current at Pmax (Imp)	7.9 Amps
Open Circuit Voltage (Voc)	36.9 Volts
Short Circuit Current (Isc)	8.09 Amps
[1] Standard Test Conditions for panel ratings: 1,000 Watts/M ² , AM 1.5, 25 C	

Figure 9: PV Module Specifications

Inverter System

SMA 7000US



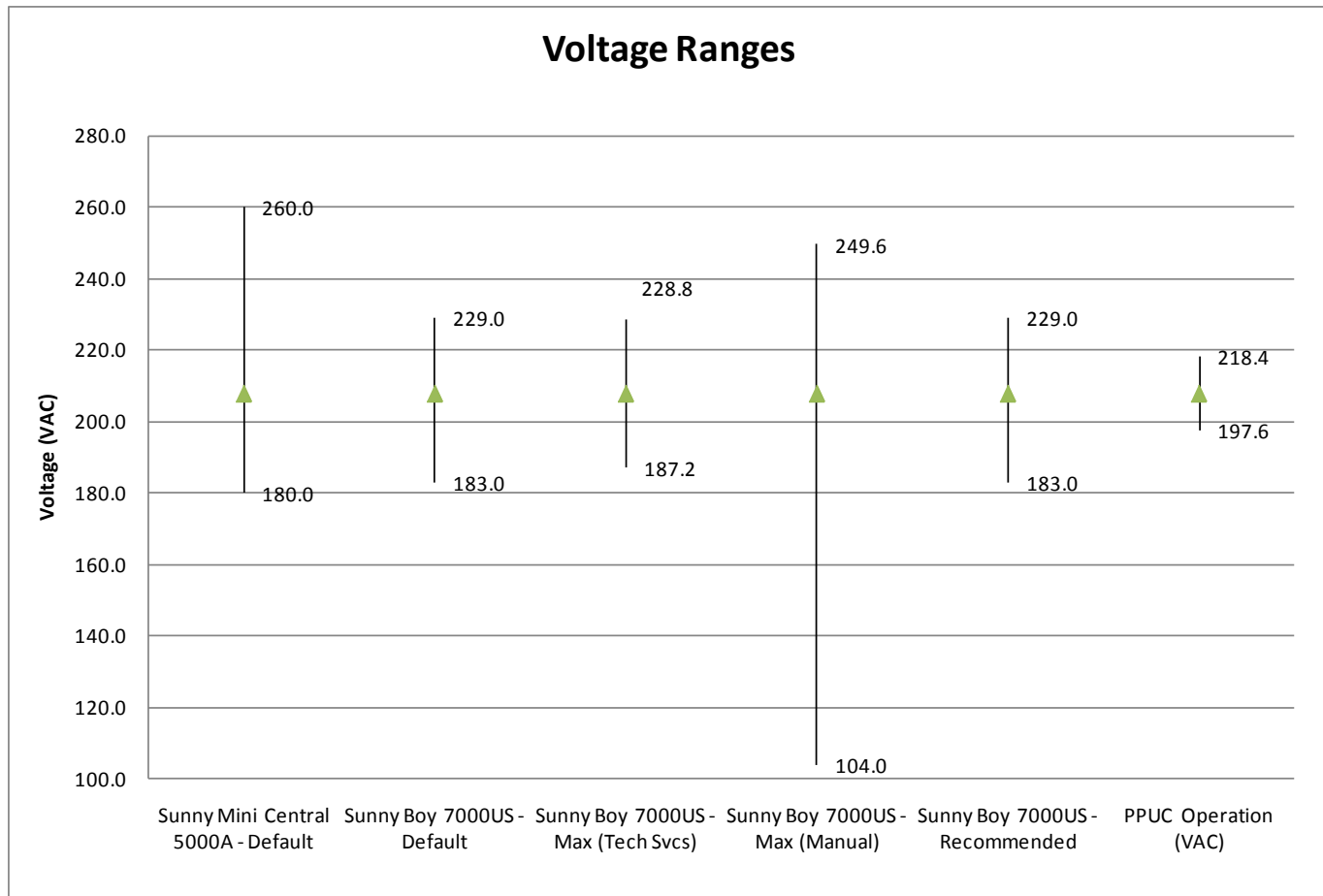
- Six SMA 7000US Inverters for system
- Reliable Product
- Rated for Outdoors Use
- Simple interface
- Integral DC Disconnect
- Several Options
- Stock Item

Critical Design Aspects

- Local Electrical Utility Performance

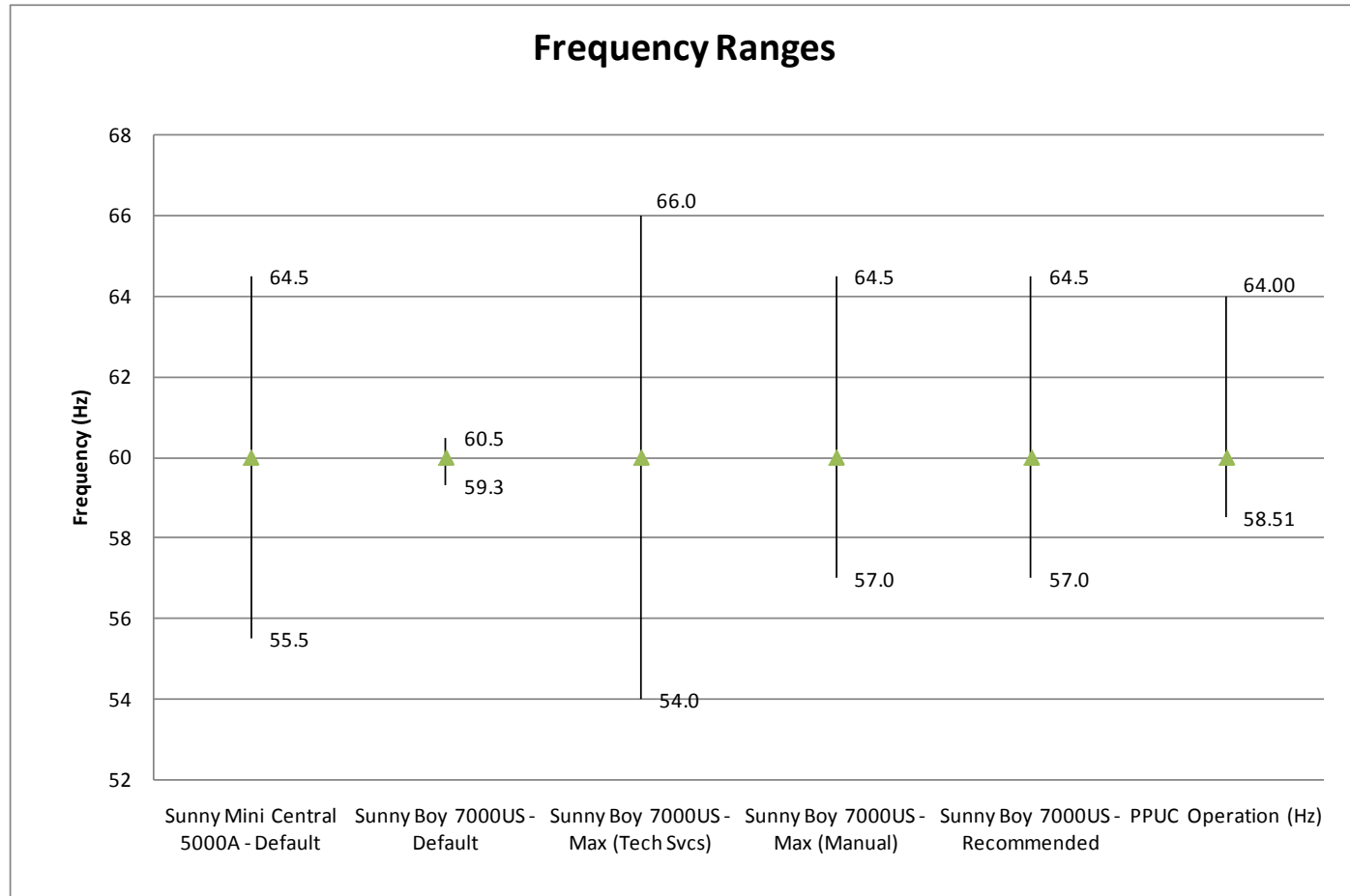
Nominal frequency	Trip limit	Trip frequencies		Trip times
60 HZ	> 60.5 Hz	60.45 Hz ... 60.55 Hz		max. 0.1602 s
	< 57.0 Hz ... 59.8 Hz (default 59.3 Hz)	56.95 Hz ... 59.85 Hz (default 59.25 Hz ... 59.35 Hz)		adjustable 0.16 s ... 300 s (default max. 0.1602 s)
	< 57.0 Hz	56.95 Hz ... 57.05 Hz		max. 0.1602 s
Nominal voltage	Trip limit	Trip voltages line-to-neutral*	Trip voltages line-to-line*	Trip times
208 V	50 %	57.6 V ... 62.4 V	99.8 V ... 108.2 V	max. 0.1602 s
	88 %	103.2 V ... 108.0 V	178.9 V ... 187.2 V	max. 2.002 s
	110 %	129.6 V ... 134.4 V	224.6 V ... 233.0 V	max. 1.001 s
	120 %	141.6 V ... 146.4 V	245.4 V ... 253.8 V	max. 0.1602 s

Critical Design Aspects



Default Voltage Operating Range is acceptable

Critical Design Aspects



Available Frequency Operating Range is acceptable

Maintenance Features

- Safety Railing
 - Maximizes Safety Considerations
 - Supports installation and maintenance
- Access Ways
 - Supports installation and maintenance
 - Beginning to be required
- Metering
 - Automatic Data Collection to quantify system performance
 - Scheduled data reports to minimize communications system impact
- Component Support
 - Global Manufacturer Technical Support (phone and online)
 - Commercial-off-the-Shelf (COTS) components
 - 10 year inverter warranty, 25 year module warranty
 - Critical spares provided to mitigate failure downtime

Maintenance Requirements

- Module Cleaning - Remove dirt, dust and debris may collect on the modules. Power washing of modules in Palau is recommended every 6 months.
- Inverter Fan Cleaning – Remove dirt, dust collected on inverter intake fans and exhaust fins every 3 months.
- System Performance – Measure and compare string voltages to identify connection or module issues every 3 months.

Simple, easy system to maintain



SUMMARY

- Training and transfer of design applications and methods to 249th EN BN
- Remaining Camp Katuu PV System Schedule (commissioning to end of monitoring and turn over to PACOM)
- System monitoring and metrics
- Estimated Camp Cost savings per year



National Defense Center for
Energy and Environment



DoD Executive Agent

Office of the
Assistant Secretary
of the Army
Installations, Energy and
Environment

www.ndcee.ctc.com

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This work was funded through the Office of the Assistant Secretary of the Army Installations, Energy and Environment and conducted under contract W91ZLK-10-D-0005 Task 0720. The views, opinions, and/or findings contained in this paper are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision unless so designated by other official documentation.